

Engineering Climate Change Negotiations

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Engineering Climate Change Negotiations

Andreas Knobel*

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Abstract

Science has recently handed us an “inconveniently simple” concept to think about climate change: to keep global temperatures from rising to dangerous levels, we may only burn a very limited amount of fossil fuels in the next hundred years. This *carbon budget* has to be shared fairly among nations.

Applying the novel approach of negotiation engineering, we propose a simple mathematical model for the climate change negotiations: to agree on a cutting of the carbon cake, parties select fairness principles and decide to which degree they should be applied. We call this “negotiation on principles”.

We investigate some properties of the model and as an application assess the fairness of past and present allocations of the budget.

Keywords: Negotiation engineering, COP 21, Paris, climate change, fairness, carbon cake, budget approach

JEL classification: F51, F64

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1 Introduction

When one of the recent rounds of United Nations climate change conferences wound up in Bonn after two weeks on 11 June 2015, parties had only managed to cut four pages from the 89-page long Geneva negotiating text¹. In the end they decided to let the two co-chairs prepare a “fully streamlined, consolidated, clear and concise version [...] that will present clear options and will not omit or delete any option or position of Parties.”²³.

Three days earlier, another meeting had closed at Schloss Elmau, Bavaria, with another declaration: the G7 leading industrial nations, source of 54% of the world’s GDP and 25% of carbon dioxide emissions, knew that “deep cuts in global greenhouse gas emissions are required with a decarbonisation of the global economy over the course of this century. Accordingly, as a common vision for a global goal of greenhouse gas emissions reductions we support sharing with all parties to the UNFCCC⁴ the upper end of the latest IPCC⁵ recommendation of 40 to 70% reductions by 2050 compared to 2010.”⁶

So, while the science is clear and all know what needs to be done, why is it so hard to negotiate an effective agreement? Climate change has been on the negotiating table for more than thirty years. Yet in these three decades annual global greenhouse gas emissions have doubled with ever increasing tendency.

The answer is of course: incompatible interests. Developed nations have built their industries on fossil fuels and want to maintain their standard of living, while developing nations – justly – want to catch up by burning especially cheap and abundant coal. At the same time it is in everybody’s interest to let global warming not run out of control.

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¹See The Guardian article <http://www.theguardian.com/environment/2015/jun/11/sluggish-pace-mars-bonn-negotiations-on-text-for-paris-climate-deal>

²See the “Way forward” document http://unfccc.int/files/bodies/awg/application/pdf/way_forward_11_june_-_edits_1026am.pdf

³This they duly did. The draft agreement published by the co-chairs on 5 October was only 20 pages. After objections by developing countries it swelled again to 51 pages.

⁴United Nations Framework Conference on Climate Change

⁵International Panel on Climate Change

⁶See p. 12 of https://www.bundesregierung.de/Content/DE/_Anlagen/G8_G20/2015-06-08-g7-abschluss-eng.pdf?__blob=publicationFile&v=5

The only ever agreement to regulate greenhouse gas emissions, the Kyoto Protocol signed in 1997 and in force since 2005, tried to come to terms with this conflict of interests by applying some fairness principles. Parties would have “common but differentiated responsibilities” under the protocol: developed nations would commit themselves to certain reduction targets, while the needs of developing nations were recognized by placing no restrictions on them (for the time being) and the provision of some technical and financial assistance for their transition to a, hopefully, low-carbon economy.

Things have changed though since Kyoto. First and foremost, some formerly developing nations have overtaken many industrialized countries in terms of greenhouse gas emissions. China is now the biggest emitter world-wide and on par with most European countries on a per capita basis.

Secondly, the adverse effects of climate change in the form of extreme weather events are now being felt not only in the least developed, vulnerable countries, but increasingly so in industrialized nations, too. At last there seems to be a growing sense of urgency in the talks.

Thirdly, recent statements by the IPCC about the state of the climate are much more confident than before saying that climate change is “unequivocal”, and that human activity is the cause of it. The IPCC is also using the conceptually simpler carbon budget approach to convey what action is required: if we want to avoid disaster, there is a rather small amount of fossil fuel that can be burnt over the next century, and it has to be shared among nations.

This has reignited the discussion about justice: how can this budget be shared fairly? Some think that every human being should be entitled to his or her slice of the carbon cake. Others want to favour those that can make best use of their share or are in most need of it.

Then how to deal with the past? Should past emissions be deducted from a nation’s current budget? That would leave some countries with rather little to go on.

When a negotiation gets tough, we should lean back and contemplate the parties’ interests. In the current climate change negotiations parties’ interests are to have some fairness principles applied. Some want to cut the carbon cake this way (citing fairness), others another way (also citing fairness).

This insight encourages us to develop a simple model for the climate change negotiations: the goal of the negotiations is to find agreement on which fairness principles should be applied to which degree when sharing the budget among parties.

The model is an instance of negotiation engineering, a technique which is being developed at the Chair of Negotiation and Conflict Management (NECOM) of the ETH Zurich (see [12]): a negotiation problem is broken into sub-problems (the definition of the applicable fairness principles) and there are parameters whose values are subject to negotiation (the emphasis given to each of them).

Using our model we can investigate which distribution of the budget different parameter settings will yield and, using some simple regression, calculate the values that were applied in the past. We shall use it as a tool to think about the climate change negotiations.

Acknowledgements

I wish to thank Dr. Sibylle Zürcher and Prof. Michael Ambühl of NECOM for fruitful discussions. I am grateful to Prof. Reto Knutti for helping me with the scientific aspects of climate change, to Swiss Ambassador Franz Perrez for sharing his experience as a negotiator in the ongoing climate change talks, to Vitalijs Butenko for discussing some game-theoretic points with me, and to Tobias Langenegger for commenting on a previous draft.

2 The Carbon Budget Idea

Carbon dioxide is the most important of the greenhouse gases simply because so much of it is produced by the combustion of fossil fuels and cement production. About three quarters of the present change in global temperatures can be attributed to it.

Whereas other greenhouse gases like methane have a fairly short lifetime in the atmosphere, carbon dioxide will, for all practical purposes, stay there forever. Climatologist James Hansen wrote in 2008⁷

⁷http://www.columbia.edu/~jeh1/mailings/2008/20080804_TripReport.pdf

“A critical fact is the long lifetime of CO₂ emitted by fossil fuel burning. Half of a fossil fuel CO₂ pulse disappears within 20-30 years, mostly into the ocean. However, much of the CO₂, about one-fifth, is still in the air after 1000 years. Because of this long CO₂ lifetime, we cannot solve the climate problem by slowing down emissions by 20% or 50% or even 80%. It does not matter much whether the CO₂ is emitted this year, next year, or several years from now. Therefore, instead of a percent reduction in the rate of emissions, we must identify a portion of the fossil fuels that will be left in the ground, or captured upon emission and put back into the ground.”

This is the idea that there is today a certain fixed *carbon budget* at our disposal. If we exceed it, we are in trouble.

So how big should the budget be? It is determined by the likely severity of possible impacts of further emissions we are willing to accept.

The consequences of global warming are already felt today, especially by poor countries least able to deal with them, and even if we decide to cut the budget to zero and cease to burn fossil fuels instantly, the effects of past emissions will be felt for a long time. On the other hand, the more we burn the *worse* the likely consequences will be, and the *more likely* the bad consequences will be. In other words: the size of the budget determines the *risk* we are taking, and the risk determines the budget.

If we are willing to accept the consequences of a temperature rise of 2°C then our budget will be bigger than if we limit ourselves to 1.5°C. If we want 95% likelihood that temperatures will not increase more than 2°C then our budget will be smaller than at 50%.⁸

Now we link the temperature changes to the budget. This is given as a function of the likelihood of a certain temperature change occurring in Figure 1⁹. Interestingly this relation is almost linear.

Since we want to include other *greenhouse gases* (GHGs) in our budget (measured in CO₂e or CO₂-equivalent units), so the coloured area is relevant.

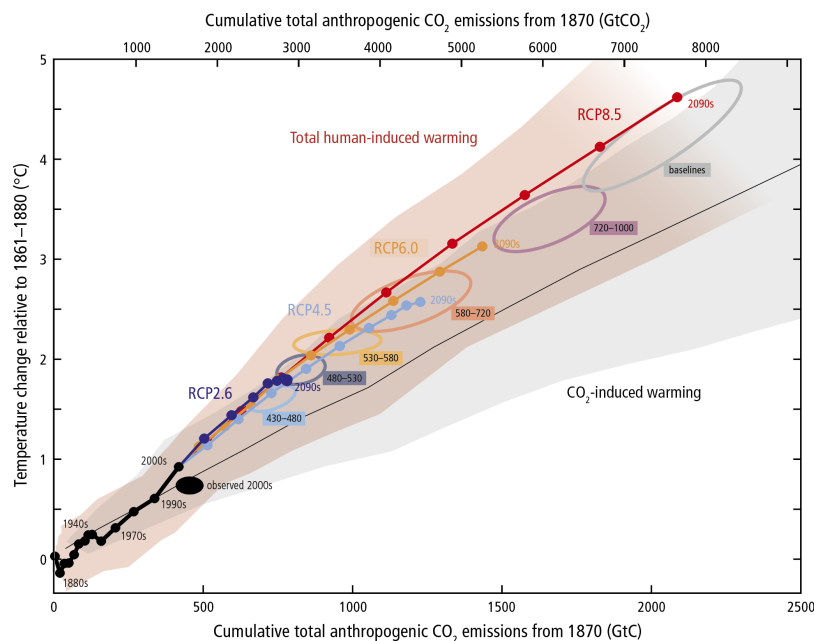


Figure 1: Budgets¹⁰

It tells us that if we wish to stay within the 2°C target with probability 50% (“equally likely than not”) we have a total budget of about 3,000 GtCO₂e. To date, we have already used up 1,800 GtCO₂e, so we have a remaining budget of 1,200 GtCO₂e. If we aim at 2°C with probability 75% then the budget is 750 GtCO₂e¹¹.

⁸An interesting account of the development of this “inconveniently simple” (in the words of climate scientist Reto Knutti) idea appears in the New York Times (<http://www.nytimes.com/2013/10/08/science/how-to-slice-a-global-carbon-pie.html?ref=science&r=3&>).

⁹1 t of carbon releases $\frac{44}{12} = 3.67$ t of carbon dioxide when burned.

¹⁰Source: IPCC AR5 [14, SYR, p. 63]. The coloured areas are all GHG emissions, the plumes represent uncertainties.

¹¹For more on this see [13]

When within the next century or so we use a certain budget is irrelevant. We can spread it thin, or we can remain on the current path and burn it all up within the next few years. From a feasibility or equity point of view however, timing is essential, and the IPCC in its most recent report urges a cut in GHG emissions of 41% to 72% on 2010 levels by 2050 and 78% to 118% by 2100 for a likely (66%) chance to stay below 2°C¹². Reduction by 118% means that some of the “overshot” carbon dioxide will have to be removed from the atmosphere by sequestration¹³.

We conclude that climate change negotiators have two tasks: they must agree on a budget and they must find a way to share it fairly.

We will no further discuss the budget here¹⁴ but take its size as given (in the examples it will be 750 GtCO₂e). We are however very interested in its equitable distribution.

3 Thinking Fairness

3.1 The UNFCCC and the Kyoto Protocol

The first legally binding international agreement that dealt with climate change was the *Kyoto Protocol*. It had been negotiated in 1997 during the third annual *Conference of Parties* (COP 3) to the *United Nations Framework Convention on Climate Change* (UNFCCC), which itself was an offspring of the Rio de Janeiro Earth Summit in 1992¹⁵.

The Kyoto Protocol made an attempt to define a fair allocation of duties by applying the two Rio principles EQUITY and COMMON BUT DIFFERENTIATED RESPONSIBILITIES (CBDR): the developed countries (roughly the OECD members) listed in Annex I of the UNFCCC gave themselves reduction targets¹⁶ (with a penalty in the case of overshooting) and had to provide financial and technical help to the developing (Non-Annex I) countries, which had no such targets and some lesser responsibilities.

3.2 The Durban Platform¹⁷

The Kyoto Protocol managed to keep greenhouse gas emissions from Annex I countries roughly steady. Nonetheless, in 2011, the year of COP 17 in Durban, annual global emissions had risen by a third, caused almost entirely by an increase in the use of fossil fuels, especially coal, in the developing world. As a result, Annex I parties were now only responsible for two fifth of global emissions.

There was also a greater sense of urgency: temperatures had risen faster than predicted, and the COP noted “with grave concern” that with current efforts chances to hold the global average temperature below 2°C or even 1.5°C were getting slim indeed (1/COP.17¹⁸).

Parties therefore at long last agreed that the old way of implementing the principles of EQUITY and CBDR by allocating burdens based on the distinction between Annex I and Non-Annex I countries was too rough and in need of an overhaul.

As a result, COP 17 launched the *Ad Hoc Working Group on the Durban Platform for Enhance Action* (ADP) and gave it the mandate to “develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention *applicable to all Parties*” by 2015 (my italics, 1/CP.17). It is remarkable that this decision had the support of the big players China, Brazil and the US, and that only India vigorously objected. The inclusion of the term “agreed outcome with legal force” was a compromise the EU made to India at the eleventh hour¹⁹. India had argued that it was unfair to developing countries to fix the form of the outcome and therefore making it legally binding for all parties before its contents were known.

¹²Table SMP.1 in http://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf

¹³This is the assumption that some future yet undeveloped technology will remove the carbon dioxide from the atmosphere. The risks of this are discussed in the UNEP Emission Gap Report [3]

¹⁴A recent very readable article is [11]

¹⁵The original text of the convention is available at <http://unfccc.int/resource/docs/convkp/conveng.pdf>, that of the Kyoto Protocol at <http://unfccc.int/resource/docs/convkp/kpeng.pdf>

¹⁶The targets are defined in Annex B to the Kyoto Protocol

¹⁷Sources: [2, Module VIII], [5]

¹⁸<http://unfccc.int/resource/docs/2011/cop17/eng/09a01.pdf>

¹⁹See an account of this in The Guardian at <http://www.theguardian.com/environment/2011/dec/11/durban-climate-deal-struck>. An explanation of the legal aspects is available from the WRI at <http://www.wri.org/blog/2011/12/q-legal-aspects-durban-platform-text>



3 a.m. huddle that produced the compromise (Credit: IISD)

The workload of the ADP was done by two “streams” of which workstream 1 had to review the role of the convention principles in the new legal agreement.

Parties submitted contradicting proposals to the ADP, developing countries wishing to maintain the Annex I-Non-Annex I distinction, while developed countries argued against it. Brazil wanted to refer to historical emissions “since 1850”, while India rejected any binding commitments for the developing countries.

The US suggested to continue with the bottom-up approach. In its submission dated 11 March 2013 to the ADP, it proposed for “Parties to define their own mitigation contributions, taking into account national circumstances, capacity, and other factors that they consider relevant.”²⁰ It argued that parties could best judge their situation and derive appropriate measures. It also thought that no alternative would work:

An approach that imposes contributions from without is neither realistic nor likely to result in wide participation/implementation. It is hard to imagine agreement on any formula or criteria for imposition of contributions, as this would get into the most controversial issues; it is also hard to imagine that Parties would be willing to have other Parties dictate their contributions, even if not based on a formula/criteria, given national sensitivities.

To address the danger of under-ambition with this approach, the US proposal suggested having a consultative period after draft contributions were put forward. This would allow parties and also the public to scrutinize the contributions and determine whether they were sufficient in view of the objective of the Convention. The consultative period would also induce parties to make their contributions clear and transparent with respect to “scope/timing/stringency/assumptions, etc.”

This idea of “self-differentiation” was adopted by the ADP, and the COP 19 in Warsaw 2013 invited parties to submit their pledges in the form of *Intended Nationally Determined Contributions* (INDCs) to the COP “by the first quarter of 2015 by those Parties ready to do so.” (1/CP.19)

What the concept of self-differentiation lacked was a reference to the principles of the Convention. If everybody defined their own efforts, would the resulting burden sharing really be fair? The COP 20 in Lima tried to address this question. The *Lima Call for Action* (Decision 1/CP.20) said, rather diffusely, that “information to be provided by Parties communicating their intended nationally determined contributions may include, as appropriate, inter alia, quantifiable information on the reference point (including, as appropriate, a base year), time frames and/or periods for implementation, scope and coverage, planning processes, assumptions and methodological approaches including those for estimating and accounting for anthropogenic greenhouse gas emissions and, as appropriate, removals, and how the party considers that its intended nationally determined contribution is fair and ambitious.”

The climate secretariat was then to give its judgement on whether with the parties’ INDCs the objective of the Convention, i.e. the 1.5 or 2°C target, could be met, or whether there was an “ambition gap,” and also assess the aggregate (but not the individual) fairness of the parties’ submissions²¹.

²⁰http://unfccc.int/files/documentation/submissions_from_parties/adp/application/pdf/adp_usa_workstream_1_20130312.pdf

²¹This synthesis report was published on 31 October 2015. It contains a list of principles which are appealed to in the INDCs but no assessment.

The Swiss INDC

As an example of how this “self-differentiation” might work, we have a quick but critical look at the INDC²² which Switzerland submitted on 27 February 2015, and which it considers to be “fair and ambitious”.

Switzerland commits itself to reduce its GHG emissions by 50% compared to 1990, of which at least 30% of the reductions are to be achieved domestically and 20% by buying carbon credits.

Switzerland claims that its contribution is consistent with scientific knowledge and the aim to keep the global temperature rise below 2°C. 50% compared to 1990 levels are in the Swiss case 51% compared to 2010 levels and so at the lower end of what is recommended by the IPCC (41% to 72%). Moreover the IPCC considers global emission reductions, and the Swiss proposal implies that everybody, including the developing countries, will be following this path. Not much differentiation there.

Next, Switzerland explains its understanding of a “fair share”, where it defines fairness in terms of responsibility and mitigation capacity and costs.

It reasons as follows (Point 6):

Responsibility is reflected in a country’s past, current and future greenhouse gas emissions. Total emissions as well as per capita emissions are to be considered.

Switzerland’s responsibility in terms of greenhouse gas emissions is low: today, Switzerland emits around 0.1% of world’s emissions and per capita emissions are at world’s average. Through climate policies implemented domestically, Switzerland’s total share in global emissions as well as per capita emissions are further decreasing despite a substantial growth in industrial production (1990 – today: +54%) and population (1990 – today: +18%). Also, Switzerland has a low level of historical emissions of around 0.2% since 1990.

Here Switzerland uses absolute numbers for total emissions, which of course are small for a country with one tenth of one percent of the world population. It is true though that per capita emissions have fallen since 1990 and are now close to the global average, and it is equally true that its industry has become substantially more efficient. Historical emissions since 1990 may account for only 0.2% of the global total, but then this is twice the average.

It is not quite clear though how these arguments support the Swiss claim that its contribution constitutes a fair share. Switzerland seems to equate fairness with “being close to average”, i.e. as per capita emissions close to the average, and this could indeed be considered fair if the past was disregarded. If historical emissions were counted as well (from, let us say, 1990), then Switzerland should have a smaller share left.

As for ambition, is aspiring to be average really sufficient?

The Swiss submission then turns to mitigation capacity, i.e. the ability to avoid greenhouse gas emissions.

Capacity to contribute to solving the climate problem is closely related to the ability to invest in appropriate mitigation measures, such as carbon-efficient technologies. Hence, one aspect of capacity is to take into account GDP per capita in fairness considerations.

Switzerland argues that affluent countries are in a better position to finance mitigation efforts and hence should carry a heavier burden than poor nations. Indeed, Switzerland’s per capita GDP (measured with purchase power parity) is currently more than four times the world average, so it would be fair that Switzerland was apportioned a *smaller* part of the budget than average.

Switzerland could also argue that current GDP and historical emissions are correlated and hence the past is already factored in when using GDP to calculate the size of a fair slice of the budget.

As a third and last point Switzerland mentions mitigation costs.

Cost-efficient mitigation potential and abatement costs are a core aspect in considering a fair contribution of a country. Abatement costs vary strongly across countries. It is also to note, that marginal abatement costs increase if a country has undertaken ambitious mitigation actions in the past. In fairness considerations, it is important to merit past efforts and reward early movers.

In Switzerland, abatement costs are high due to the limited availability of short term cost-efficient mitigation potential: Switzerland’s energy production is nearly carbon free and there is little heavy

²²Available at http://www4.unfccc.int/submissions/INDC/Published%20Documents/Switzerland/1/15%2002%2027_INDC%20Contribution%20of%20Switzerland.pdf

industry. Emission reduction potential mostly remains in the housing and transport sectors. This remaining potential has long transformations periods.

Here Switzerland argues that it should get a *bigger* share than average because prices in Switzerland are generally high, and cheap means of reducing greenhouse gas emissions have largely been exhausted. This is also the reason why Switzerland plans to achieve parts of its emission reductions abroad.

To sum up, Switzerland considers a fair share of the greenhouse budget for a country to be one proportional to the size of its current population, with an upward adjustment for its (in its view) low historical emissions, as well as a downward adjustment for its mitigation capacity, measured in its economic performance, and an upward adjustment for its mitigation potential, measured in marginal abatement costs²³.

3.3 Sharing the Budget

It is time to become more specific about those principles we have been alluding to.

The Swiss submission appeals to four principles by which the emission budget could be shared: EQUAL PER CAPITA, HISTORICAL RESPONSIBILITY, ABILITY TO PAY and EQUAL BURDENS. They and others have been widely discussed in the philosophical literature in a recently established branch of ethics: *climate justice*.

Sharing the emission budget is the seemingly simple matter of

1. allocating shares of the emission budget to parties;
2. adjusting for past emissions;
3. allowing countries to trade parts of their shares.

We start by looking at different ways of sharing the current budget, which in Section 2 we defined to be 750 GtCO₂e. We are not interested in how the budget is spent, i.e. whether our generation spends it or the next, but we will not allow “overshooting”. Later we shall consider the past and discuss whether our current budget should be adjusted for historical emissions.

Trading slices is a necessity since parties might end up with a negative amount if a principle is applied, and we shall assume that some market mechanism is in place similar to the one provided by the Kyoto Protocol.

We draw our insights from a number of sources: Grasso [8] gives a brief overview. This is our main source for the next section. Gardiner et al. [7] is a collection of “essential readings” on climate ethics by a number of authors, and Peter Singer has added a new chapter on climate change to his work *Practical Ethics* [16].

3.4 Fairness Principles

EQUAL PER CAPITA

The most intuitive way to share the carbon budget is to give a slice of identical size to every person on Earth. Straightforward as it might seem, this approach has its problems.

First of all, it is not clear which reference year should be used for population size. Between the years 1990 and 2010, India added 40%, Nigeria 70% to its population, whereas it was almost stable in Japan. Maybe taking the average over some period might help, but since the budget concerns the future, the size of a party’s population in ten or twenty years should be taken into account, too.

Predictions of this kind are however difficult to make. Should we extrapolate from the current age structure? 22% of the Japanese are younger than 25, whereas this number is 66% in Nigeria. On the other hand, life expectancy at birth in Nigeria is only 52 years, while the Japanese on average live up to 85²⁴. Also it could be argued that allocating the budget based on future population numbers is an incentive for countries to encourage population growth, which is certainly something we would want to avoid.

²³Marginal abatement costs are the costs of the cheapest available measures to reduce emissions.

²⁴2014 numbers. Source: CIA World Factbook

EQUAL ACCESS

There is another complicating factor: people may not get the same benefit out of burning one ton of coal.

Let us consider heating or cooling for instance: how much energy is needed to keep one's home at a pleasant temperature depends of course on the local climate. Similarly does living in a sparsely populated area increase one's need for transportation. Should this unequal access to some basic services not be compensated by a larger share of the emission budget? Or would this compensation reduce the incentive to make these services more efficient?

BASIC NEEDS

On the other hand, maybe everybody should receive a share of the budget which meets their basic needs and the remainder could be distributed following some other principle.

What is problematic with this approach is that there is wide disagreement among individuals and countries as to how much is enough. For US President George H. W. Bush for instance there is clearly no limit. As early as 1992 he rejected criticism of the American rather wasteful way of life by saying ahead of the Earth Summit that it was "not up for negotiation. Period."

EQUAL BURDENS

The cost of mitigation also varies considerably. First of all, in general prices differ across countries even when they are adjusted for purchasing power or GDP. But marginal costs in a country which has invested heavily in mitigation will also be high since it will have exhausted the cheap means to reduce emissions. A per head allocation of the budget on the other hand would favour the laggards.

ABILITY TO PAY

Apart from cost, there is also the ability to pay which should be taken into consideration. Even when mitigation costs are high, if a party can afford to pay then it should. Usually GDP is taken as an indicator for this principle.

HISTORICAL RESPONSIBILITY

Developed countries have grown rich on fossil fuel and thereby caused much of the current global warming. At the same time, they are in a much better position to deal with the sometimes disastrous consequences than the developing world. The principle of HISTORICAL RESPONSIBILITY tries to remedy this injustice by taking into account past emissions when allocating shares of the budget.

But did we have enough evidence to link global warming to anthropogenic emissions?

GRANDFATHERING

Finally, the principle of GRANDFATHERING allocates future emissions in proportion to past or current emissions. It is not equitable since it rewards those who have with more. Nevertheless, this was the principle used in the Kyoto Protocol, at least for the industrialized countries, and it is being used again in preparation for Paris.

Conclusion

In this section, we have talked about fairness and listed some principles used in the climate change context. Can we use them to find a just allocation of the carbon budget? This is the topic of the main part of the thesis, where we will present our model of negotiation. But first some words about Negotiation Engineering.

4 Negotiation Engineering

Negotiation Engineering is a method to deal with complex negotiations which is being developed and taught at the Chair of Negotiation and Conflict Management of the ETH Zürich under the leadership of Prof. Dr. Michael Ambühl.

In Negotiation Engineering an intractable problem is broken up into more manageable sub-problems. These are then solved using scientific or other methods based on objective criteria. Often a problem will be expressed in terms of a mathematical model whose parameter values are then subject to negotiation.

Notice the reliance on science and facts: it is based on the conviction that in a negotiation ultimately reason will prevail.

A recent application of Negotiation Engineering to the problem of immigration and the free movement of persons between the European Union and Switzerland can be found in [4].

In this thesis we shall attempt to apply Negotiation Engineering to the problem of finding an equitable distribution of the greenhouse gas emission budget. We introduce a simple mathematical model which will allow us to translate fairness principles into allocations of shares to parties participating in the negotiation. Applying principles in varying degrees and in combination lets us move easily between opposing positions.

5 A Model for Negotiation on Principles

For illustration purposes and to apply the model, we select parties with different backgrounds and interests: island states, China, the twenty-eight European Union members, India, Switzerland and the USA. They currently account for more than half the world's GHG emissions. The other parties we treat together as the rest of the world (RoW).

The *Alliance of Small Island States* (AOSIS) is a group of low lying countries that have arguably contributed least to climate change yet suffer most from it. Members include countries like Tuvalu and Vanuatu, which are also on the UN's *Least Developed Countries* (LDC) list, but also rich Singapore. GHG emissions from these countries have steadily increased over the past twenty-five years, but have always been at a lower level than the global average.

China's emissions on the other hand have soared in the same period because of its economic growth and use of coal to feed it. In absolute terms it is currently the biggest emitter of greenhouse gases and responsible for about one quarter of the global annual total of 43 GtCO₂e. Its emissions per capita are also greater than average and range now above those of many industrialized countries, e.g. Switzerland. To be fair, one has to add that much of China's heavy industry now works to satisfy Western demand.

Emissions from the twenty-eight European Union countries have, in relative terms, decreased considerably but are still above world average. The decline is thanks to the fact that many of the former Eastern Bloc's inefficient factories have been closed down or replaced by more efficient ones.

India's emissions per capita are the lowest of all the parties considered here, only a third of the global average. Industrialization has not been at the same pace as China's but India is keen to catch up.

Switzerland's total emissions have been roughly stable over the past twenty-five years and on a per capita basis have fallen by one fifth. Switzerland is interesting because it is a small country and could be instrumental in forming alliances among other parties. It is one of the five members of the UNFCCC *Environmental Integrity Group* (EIG), the only grouping with countries representing rather diverse interests.

Finally, the USA is the biggest emitter of greenhouse gases per capita in this list at almost three times the European level, although this value has been coming down lately.

5.1 Notation

We introduce some notation.

In general, we have $n \geq 2$ parties to the negotiations. Let Π denote a *principle* which assigns a fraction p_i^Π of the global budget B to each party i . Denote party i 's budget by B_i^Π . The fractions p_i add up to 1 but they can be negative (meaning a party has *debts*) or larger than 1 (meaning a party is owed by the others).

If we wish to look at budgets or fractions of a particular year y we indicate this by writing ${}_yB$ or ${}_yp$.

P stands for (global) *population*, E for (global) *emissions*, ${}_yE$ for emissions of a certain year, and ${}_{y_0}E$ for aggregate emissions from (and including) year y_0 up to (and not including) year y_1 .

More notation will be introduced as we go along or will be self-explanatory.

5.2 Introductory Example: EQUAL PER CAPITA Versus GRANDFATHERING

We start by looking at the two principles EQUAL PER CAPITA and GRANDFATHERING, which we discussed in Section 3.4.

Definitions

EQUAL PER CAPITA means that allocation is according to population size. So let B_i^{EPC} be party i 's share of the budget according to EPC. We have

$$p_i^{\text{EPC}} = \frac{P_i}{P}$$

and hence

$$B_i^{\text{EPC}} = B \times p_i^{\text{EPC}} = B \times \frac{P_i}{P}$$

GRANDFATHERING on the other hand allocates a share of the budget to a party i which is proportional to its share of GHG emissions or

$$p_i^{\text{G}} = \frac{E_i}{E}$$

and hence

$$B_i^{\text{G}} = B \times p_i^{\text{G}} = B \times \frac{E_i}{E}$$

If we let A denote global emissions per capita and A_i emissions per capita of a party i (A for *average*) we can write $E = P \times A$ and $E_i = P_i \times A_i$ and have

$$B_i^{\text{G}} = B \times \frac{E_i}{E} = B \times \frac{P_i \times A_i}{P \times A} = B \times \frac{P_i}{P} \times \frac{A_i}{A} = B_i^{\text{EPC}} \times \frac{A_i}{A}$$

From this we note that GRANDFATHERING is more favourable to a party if its average emissions are higher than the global average, whereas EQUAL PER CAPITA favours countries with low emissions.

Mixing EQUAL PER CAPITA and GRANDFATHERING

In order to represent positions between these two opposing principles we simply take the linear combination of the two. So let $0 \leq \alpha \leq 1$ and define for party i

$$p_i^{\alpha\text{G}+(1-\alpha)\text{EPC}} := \alpha p_i^{\text{G}} + (1 - \alpha) p_i^{\text{EPC}}$$

and

$$B_i^{\alpha\text{G}+(1-\alpha)\text{EPC}} := B \times p_i^{\alpha\text{G}+(1-\alpha)\text{EPC}}$$

We note that by linearity for any α , the fractions of the different parties add up to a whole.

Picking Base Years

Let us have a look at the the year 2010, which is the second last year for which this data is available²⁵. We get the following allocations for EQUAL PER CAPITA, GRANDFATHERING and an even mixture of the two:

²⁵Source of all data in the examples: WRI, CAIT 2.0. 2014. Climate Analysis Indicators Tool: WRIs Climate Data Explorer. Washington, DC: World Resources Institute. Available at: <http://cait2.wri.org>.

Party	Emissions ²⁶	Population million	Em. per capita tCO ₂ e	Percentage of Global Budget		
	MtCO ₂ e			EPc	$\alpha = 0.5$	G
AOSIS	276.99	56.70	4.89	0.82	0.74	0.65
China	9,679.30	1,327.71	7.24	19.43	21.06	22.68
EU28	4,663.41	501.54	9.30	7.28	9.11	10.93
India	2,432.18	1,205.63	2.02	17.51	11.61	5.70
Switzerland	53.94	7.83	6.89	0.11	0.12	0.13
USA	6,668.79	309.33	21.56	4.49	10.06	15.63
RoW	18,895.11	3,466.49	5.45	50.35	47.31	44.28
World	42,669.72	6,885.22	6.20	100	100	100

Table 1: Allocations under different principles (base year 2010)

As was mentioned before, countries with higher than global average emissions per capita do better under GRANDFATHERING than under EQUAL PER CAPITA, and it pays countries to pollute today because then they can pollute more in the future. Yet this is precisely the principle on which the Kyoto Agreement is based.

If we take 1990 as the base (cf. Table 2), the reference year for most reduction targets in Annex B of the Kyoto Protocol, although only for some countries, the picture changes completely. Here China is much better off with EQUAL PER CAPITA than GRANDFATHERING.

For the European Union, which is still above the global average, but whose emissions at that time were much higher, the gap between the two schemes is much bigger.

Party	Emissions	Population million	Em. per capita tCO ₂ e	Percentage of Global Budget		
	MtCO ₂ e			EPc	$\alpha = 0.5$	G
AOSIS	180.15	42.90	4.20	0.81	0.70	0.58
China	3,355.55	1,135.19	2.96	21.50	16.19	10.87
EU28	5,384.83	473.07	11.38	8.96	13.20	17.44
India	1,082.51	868.89	1.25	16.46	9.98	3.51
Switzerland	52.78	6.72	7.86	0.13	0.15	0.17
USA	5,990.91	249.62	24.00	4.73	12.06	19.40
RoW	14,833.77	2,502.55	5.93	47.41	47.73	48.04
World	30,880.50	5,278.93	5.85	100	100	100

Table 2: Allocations under different principles (base year 1990)

How Principled Was Kyoto?

We now ask the question how much the allocation of the individual budgets to our six parties matched the application of the two principles EMISSIONS PER CAPITA and GRANDFATHERING. Had countries decided in 1997 to use our principled approach and agreed on an α , could we from the result today infer what the most likely value would have been?

Of course only Annex I countries made pledges, and AOSIS, China and India were left to do business as usual. So for the EU28, Switzerland and USA we take their pledged reductions based on the parties' emissions in 1990 whereas for AOSIS, China and India we take the actual emissions in 2010. For the world we do likewise: pledges for Annex I countries, real emissions for the others. We let the budget 2010 be the sum of these two numbers.

²⁶All figures excluding emissions from land-use change and forestry

Doing so we get three numbers for each party: its fraction p^{EPC} of the budget 1997 calculated with EQUAL PER CAPITA, its fraction p^{G} calculated with GRANDFATHERING, and its fraction of the current budget p . We want to find the α which for this set of data best describes the relation

$$\alpha p^{\text{G}} + (1 - \alpha)p^{\text{EPC}} = p$$

To achieve this we do a simple linear regression²⁷ with variable α and obtain the result $\alpha = 0.56$ with a fairly large standard error of $se = 0.16$ indicating that *on average* there was rather more GRANDFATHERING applied than EQUAL PER CAPITA with large deviations for individual parties. Had parties decided to apply the two principles with a ratio of 0.56 : 0.44 then the fractions in the last column would have resulted.

Party	% of Budget 1997 p^{EPC}	Pledges for 2010 p^{G}	Emissions in 2010 MtCO ₂ e	% of Budget 2010 p	% of Budget 2010 with $\alpha = 0.56$
AOSIS	0.82	0.61		0.65	0.70
China	20.99	13.66		22.86	16.88
EU28 ²⁸	8.21	15.46	4,954.04	11.70	12.27
India	16.90	4.34		5.74	9.86
Switzerland	0.12	0.16	48.55	0.11	0.14
USA	4.65	20.37	5,571.55	13.16	13.46
World	100	100	17,229.73	100	100

Table 3: KP pledges and actual emissions

We see that most parties got what they would have had if this size of α had been decided in a negotiation with the notable exception of China and India: China now has a lot more, and India a lot less.

5.3 Mixing Principles: the General Model

We now generalize what we did in the previous section.

Definition. A *Model of Negotiation on Principles*²⁹ for n parties consists of

1. a family $\{\Pi_j\}_{0 \leq j < k}$ of k principles each defining a family of fractions of 1, i.e. n real numbers $\{p_i^{\Pi_j}\}_{0 \leq i < n}$ such that $\sum_i p_i^{\Pi_j} = 1$ for all j .
2. k real non-negative weights α_j such that $\sum_j \alpha_j = 1$.

Also for k principles Π_j and k weights α_j we define the principle $\Pi = \alpha_0 \Pi_0 + \dots + \alpha_{k-1} \Pi_{k-1}$ by setting for all i

$$p_i^{\alpha_0 \Pi_0 + \dots + \alpha_{k-1} \Pi_{k-1}} := \alpha_0 p_i^{\Pi_0} + \dots + \alpha_{k-1} p_i^{\Pi_{k-1}}$$

We can easily check that the fractions thus defined add up to 1.

5.4 Assessing Proposals

Using regression as we did in the previous section we can assess the degree to which the different principles were used to define a certain allocation of the budget to parties.

²⁷We first need to transform this equation to

$$\alpha(p^{\text{G}} - p^{\text{EPC}}) + u = p - p^{\text{EPC}}$$

²⁸In 1997 this was still the EU15

²⁹This notion has to be distinguished from Fisher and Ury's *principled negotiation* introduced in [6]

Simply let p be the proposed fraction of the budget for all parties and let p^{Π_j} their fraction by principle j , $0 \leq j < k$, then do a multiple linear regression for

$$\sum_{j=0}^{k-2} \alpha_j p^{\Pi_j} + (1 - \sum_{j=0}^{k-2} \alpha_j) p^{\Pi_{k-1}} = p$$

5.5 Example continued: Setting α

When weighing EQUAL PER CAPITA against GRANDFATHERING, how can we find a suitable α ?

Here is a suggestion: the cost of abated greenhouse gas emissions depends on local factors and rises as measures are implemented. Figure 2 gives an indication of the *global marginal costs*. Similar curves have been worked out for some individual countries.

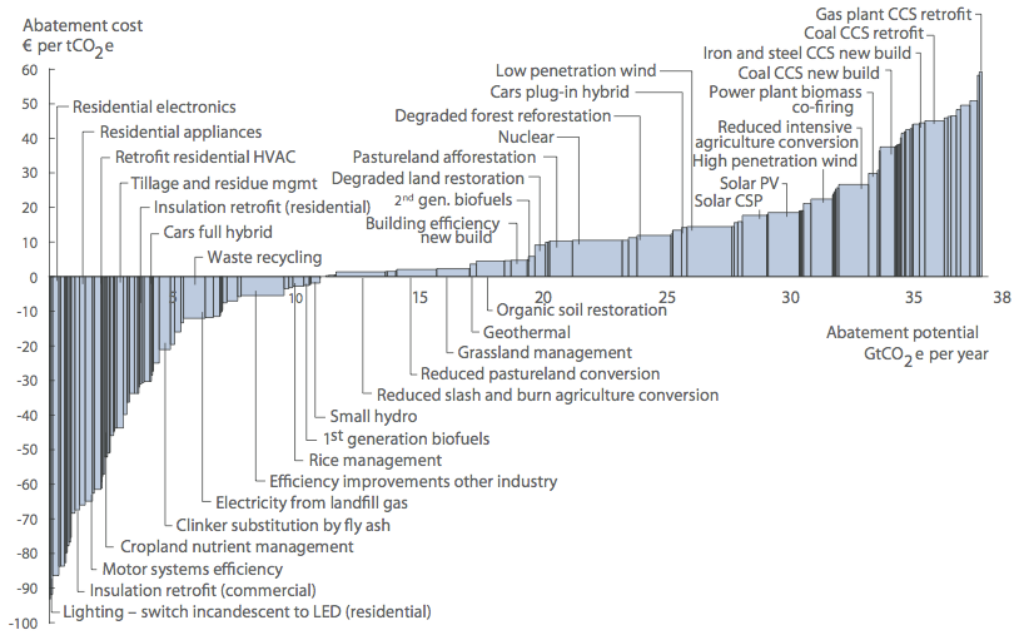


Figure 2: Global marginal abatement costs³⁰

We see that many measures to lower emissions actually save money, while others cost money but are relatively cheap to implement. It therefore makes sense to choose the α in a way that the overall costs to countries is minimal.

5.6 Dealing With Historical Emissions

Next we turn to historical emissions. Here the question is whether historical emissions should be taken into account when calculating the budget.

If we decide that past emissions should be disregarded then allocations are as defined in the previous section.

On the other hand, we could also decide to have emissions count in their entirety starting from some year in the past when calculating the budget for the current year.

Let us again look at an example. If in 2010 we have a global budget of 750 GtCO₂e to keep the 2°C limit with 75% probability then in 1990 we had a budget of 750 GtCO₂e plus the aggregated global emissions in between. Based on this global budget and using 1990 numbers we can calculate what each party's budget would have been for 1990 and then subtract its emissions since then to arrive at its adjusted budget for 2010. In details:

³⁰Source: McKinsey [1]

1. The total budget in 1990 consists of the budget of 2010 plus the aggregated global emissions

$${}_{1990}B = {}_{1990}^{2010}E + {}_{2010}B$$

2. For every party i we calculate its fraction of the total budget according to some principle Π for year 1990 as defined above. We have already listed the resulting percentages in Table 2.
3. We then subtract the emissions of party i since the base year from its share to arrive at its present budget

$${}_{2010}B_i^\Pi = {}_{1990}B_i^\Pi - {}_{1990}^{2010}E_i$$

4. We calculate its fraction of the total budget as

$${}_{2010}P_i^\Pi = \frac{{}_{2010}B_i^\Pi}{{}_{2010}B^\Pi}$$

Party	Percentage of Budget 1990			Emissions 1990–2010 MtCO ₂ e	Percentage of Budget 2010		
	EPC	$\alpha = 0.5$	G		EPC	$\alpha = 0.5$	G
AOSIS	0.81	0.70	0.58	4,550.64	1.01	0.76	0.55
China	21.50	16.19	10.87	119,507.20	26.74	14.42	5.66
EU28	8.96	13.20	17.44	105,534.84	3.71	10.73	20.53
India	16.46	9.98	3.51	33,730.55	28.17	10.60	2.48
Switzerland	0.13	0.15	0.17	1,110.79	0.10	0.14	0.19
USA	4.73	12.06	19.40	137,847.05	-8.99	0.63	20.12
RoW	47.41	47.72	48.03	336,204.77	49.26	62.72	50.47
World	100	100	100	738,485.94	100.00	100.00	100.00

Table 4: Allocations (less historical emissions since 1990)

Looking at Table 4 we note that allocations change considerably if historical emissions are included in the calculation.

Under EQUAL PER CAPITA the USA would now owe the rest of the world a tenth of the global budget and have to become GHG-neutral instantly, something which is neither realistic nor acceptable to the Americans. On the other hand, under GRANDFATHERING they would even have gained a little having come down slightly from a high level whereas much of the rest of the world moved in the opposite direction.

If historical emissions are part of the calculations, China loses some of its budget under GRANDFATHERING since its emissions in 1990 were still very low but then accelerated, but it also gains when Equal per Capita is applied.

India has used up less of its 1990 budget than China and has thus gained under EQUAL PER CAPITAL while it has lost under GRANDFATHERING. The two fractions now differ by a factor of 14.

So how could we make a moral argument for or against the inclusion of historical emissions in our calculations and define an acceptable model?

We saw in Section 3.4 that an argument in favour of inclusion is that it rewards the countries that heeded the warnings of the scientists and reduced their emissions and punishes those that in the face of the evidence continued to do business as usual. So while there might be agreement on the justice of this, people might argue there was not sufficient evidence of global warming in the past to warrant decisive action.

Let us consider what the scientists of the IPCC told us about climate change over the years:

Report	Year	Assessment
1st	1990	The planet seems to be warming.[9]
2nd	1995	“The balance of evidence ...suggests a discernible human influence on the global climate system.”[10, p. 5]
3rd	2001	“...most of the warming observed over the last 50 years is attributable to human activities.”[17, SPM, p. 5]
4th	2007	“Warming of the climate system is now unequivocal.”[15, SPM, p. 2]
5th	2014	“Human influence on the climate system is clear.”[14, SPM, p. 2]

Table 5: Assessments of Evidence for Global Warming in the IPCC Reports

We see that every five years or so that the IPCC published its reports, the evidence got stronger that the climate gets warmer and that this warming is due to human activity. We can argue that countries that have ignored this evidence should have their historical emissions subtracted from their original budget in ever higher degrees. Or, looking in the opposite direction we might say: we wish to progressively *discount* emissions as we move into the past. But by how much should we discount them? If we take as a measure of the spread of knowledge of climate change the number of citations of peer reviewed articles, we see in Figure 3 that this number has been growing nearly exponentially since 1990. We therefore decide to discount the past in our model with a constant factor δ .

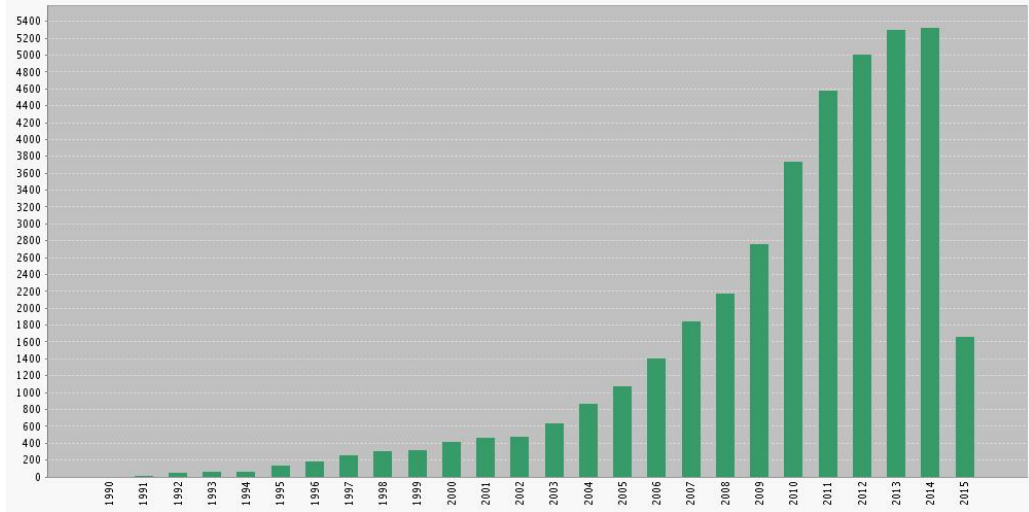


Figure 3: Citations of peer reviewed articles with "global warming" or "global climate change" as topic³¹

These thoughts lead us to change our previous all-or-nothing approach and introduce a more flexible model:

1. We let the discount factor δ be a real number between 0 and 1. A factor δ of 0 means we are ignoring the past, and a factor of 1 that past emissions count 100 percent.
2. The total budget in 1990 now consists of the budget of 2010 plus the discounted aggregated global emissions of the 5-year periods since 1990

$${}_{1990}B = \delta^4 {}_{1995}^{1995}E + \delta^3 {}_{1995}^{2000}E + \delta^2 {}_{2000}^{2005}E + \delta {}_{2005}^{2010}E + {}_{2010}B$$

3. For every party i we have already calculated its fraction ${}_{1990}B_i^\Pi$ of the total budget according to some principle Π for the year 1990.
4. We then subtract the emissions of party i since the base year from its original share to arrive at its current budget of

$${}_{2010}B_i^\Pi = {}_{1990}B_i^\Pi - \delta^4 {}_{1995}^{1995}E_i - \delta^3 {}_{1995}^{2000}E_i - \delta^2 {}_{2000}^{2005}E_i - \delta {}_{2005}^{2010}E_i$$

³¹Source: Thomson Reuters, Web of Science

5. We calculate its fraction of the total budget as

$${}_{2010}p_i^\Pi = \frac{{}_{2010}B_i^\Pi}{{}_{2010}B^\Pi}$$

Selecting δ

How large should δ be? Figure 3 suggests that the number of citations grew from an average of 100 during the five years starting in 1990 to 5000 during the years from 2005. Hence we have a 50-fold increase over three periods, or

$$\delta^{-3} = 50$$

from which we obtain $\delta = 0.27$.

Inserting this number into our formula we obtain the following allocations:

Π	Party	Percentage of budget with a discount factor δ of		
		0	0.27	1
EPC	AOSIS	0.81	0.83	1.01
	China	21.50	21.71	26.74
	EU28	9.05	8.60	3.71
	India	16.46	17.55	28.17
	Switzerland	0.13	0.13	0.10
	USA	4.73	3.52	-8.99
$\frac{1}{2}\text{G} + \frac{1}{2}\text{EPC}$	AOSIS	0.69	0.71	0.76
	China	16.19	15.90	14.42
	EU28	13.24	13.24	10.73
	India	9.98	10.46	10.60
	Switzerland	0.15	0.15	0.14
	USA	12.06	11.55	0.63
G	AOSIS	0.58	0.57	0.55
	China	10.87	10.08	5.66
	EU28	17.44	17.87	20.53
	India	3.51	3.38	2.48
	Switzerland	0.17	0.17	0.19
	USA	19.40	19.58	20.12

Table 6: Percentages of global budget in 2010 as a function of α and δ

We see that because of the small factor deviations from ignoring the past altogether are minimal. Nonetheless, if considered valid at all, the knowledge argument might be used to fine-tune the allocations.

6 How Realistic Is the Model?

Let us reflect on what we have just done: we introduced our simple model of negotiation building on fairness principles. Each principle defines an allocation of the greenhouse gas budget to the parties. Negotiators have to agree on how much weight they want to give to each principle to arrive at a fair distribution.

What then are the chances that the 196 parties to the Convention will agree on an allocation of the carbon budget in Paris?

Executive secretary of the UNFCCC Christiana Figueres said in a recent article that carbon budgets were a good scientific exercise but that they could not be the basis for negotiations. “I don’t think it’s possible,” she told the Guardian³² in an interview. “Politically it would be very difficult. I don’t know who would hold the pen [in setting out allocations of future budgets].”

As we discussed in Section 3.2 the United States concurred³³: “It is hard to imagine agreement on any formula or criteria for imposition of contributions, as this would get into the most controversial issues.”

Yet it is the same parties that in Cancún in 2011 set themselves the following mitigation objectives³⁴:

1. Establish clear goals and a timely schedule for reducing human-generated greenhouse gas emissions over time to keep the global average temperature rise below two degrees.
2. Review progress made towards two-degree objective, and a review by 2015 on whether the objective needs to be strengthened in future, including the consideration of a 1.5°C goal, on the basis of the best scientific knowledge available.

This, together with the 2013 unanimously³⁵ accepted link between the degree of future global warming and the amount of greenhouse gases that could still be emitted, implies the existence of a greenhouse gas budget.

Furthermore the third objective implies that the budget should be split fairly among the parties:

3. Encourage the participation of all countries in reducing these emissions, in accordance with each country’s different responsibilities and capabilities to do so.

What is not specified in these objectives is the timing. In our model we assume that the budget is allocated once and top-down. That is what Christiana Figueres considers politically very difficult. As we saw in Section 3.2, what is being tried now is a phased bottom-up approach: parties submit their proposals for what they deem to be a fair share for a first phase and will later meet again to reconsider.

Let us try to see in our model how a phased *top-down* approach would fare.

Bottom-Up

First we go back to our introductory example in Section 5.2 and see what will happen if our six parties and the rest of the world each define an allocation based on the two available principles of EQUAL PER CAPITA and GRANDFATHERING. Let us further maliciously assume that they all opt for the principle that is most beneficial to them. From Table 1 we get the following allocations:

Party	Percentage of Global Budget
AOSIS	0.82
China	22.68
EU28	10.93
India	17.51
Switzerland	0.13
USA	15.63
RoW	50.35
World	118.05

Table 7: Allocations by individually most beneficial principle (base year 2010)

³²<http://www.theguardian.com/environment/2013/oct/24/ipcc-carbon-budget-warsaw-climate-change-christiana-figueres>

³³https://unfccc.int/files/documentation/submissions_from_parties/adp/application/pdf/adp_usa_workstream_1_20130312.pdf

³⁴http://unfccc.int/key_steps/cancun_agreements/items/6132.php

³⁵See E.8 of the Summary for Policymakers of the Assessment Report of WG1 at https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WGIAR5_SPM_brochure_en.pdf. The SPM is approved line by line by all 196 parties to the convention.

We see that with the bottom-up approach parties overshoot the budget by one fifth although they can all claim to have taken a principled approach.

A Phased Top-Down Approach

While a bottom-up approach is not likely to work, releasing the budget in phases while working top-down might actually be a good idea.

The main argument for a phased approach is that circumstances change: knowledge increases, technology advances, countries are transformed. An allocation of the greenhouse gas budget based on whichever mix of principles is certain to change over time. It therefore makes sense to reassess the situation periodically, say every ten years. This would have to be done the following way:

1. Apportion the total budget to the next decades in line with the recommendations of the IPCC (see Figure 4).
2. At the start of every decade allocate the next portion of the budget to the parties based on the new situation.

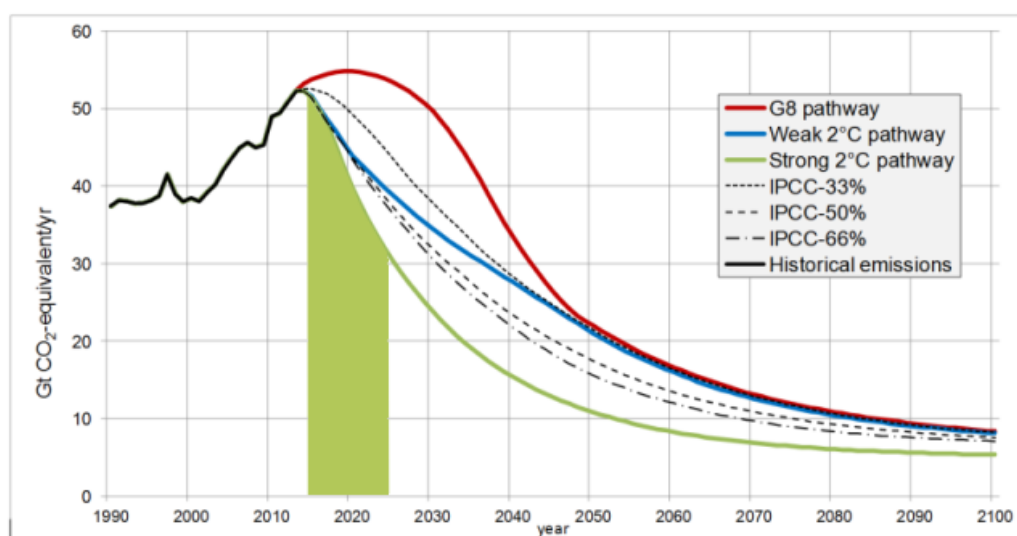


Figure 4: Phased approach (The green area represents the first portion of the 750 GtCO₂e budget)³⁶

Conclusion

To sum up: we do think that our approach is realistic, and is in fact a consequence of what the UNFCCC process has produced to date. Working bottom-up however is not likely to work and will overshoot, while a phased top-down approach might be acceptable to parties while staying within the budget.

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³⁶Image adapted from gdrights.org

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